Original Article

Are there any novel radiological diagnostic clues in magnetic resonance imaging for vertebrobasilar insufficiency?

Emin Cakmakci[1], Safiye Tokgoz Ozal[2], Esra Karabay Ogutcu[3], Alper Aydin[4], Suzan Tunc[5], Umut Kaygusuz[6], Hasibe Gokce Cinar[1]

[1]Department of Radiology, Dr. Sami Ulus Children's Health and Diseases Training and Research Hospital, Ankara, Turkey; [2]Department of Radiology, Kartal Dr. Lutfi Kirdar Training and Research Hospital, Istanbul, Turkey; [3]Department of Radiology, Iskenderun Government Hospital, Iskenderun, Turkey; [4]Department of Radiology, Giresun Prof. Dr. A. Ilhan Ozdemir Government Hospital, Giresun, Turkey; [5]Department of Radiology, Malatya Government Hospital, Malatya, Turkey; [6]Department of Otorhinolaryngology, Dr. Sami Ulus Children's Health and Diseases Training and Research Hospital, Ankara, Turkey

Correspondence to: Emin Cakmakci, MD. Department of Radiology, Dr. Sami Ulus Children's Health and Diseases Training and Research Hospital, Ankara, Turkey. Email: em_sel74@hotmail.com.

Background: The aim of the current study was to investigate whether signal intensities on magnetic resonance imaging (MRI) views and radiological findings on Doppler ultrasonography may have a diagnostic value for vertebrobasilar insufficiency (VBI).

Methods: This case-control study was performed on demographic and radiologic data derived from 18 VBI patients and 58 healthy controls in the radiology department of a tertiary care center. The blood flow characteristics including peak systolic and end diastolic flow rates, resistance and pulsatility indices, mean velocities, flow rates, diameters and intensity pattern of vertebral arteries on cervical and cranial MRI sequences were noted. The association between blood flow characteristics and signal patterns on MRI views was investigated in VBI patients and controls.

Results: Blood flow and vessel diameter were significantly decreased in VBI patients compared to controls on both sides (P<0.001). In contrast, other parameters did not exhibit any remarkable difference between VBI and control groups. The distribution of hypo- or hyperintense signals in VBI and control groups was similar. No remarkable variabilities were detected in blood flow characteristics of cases presenting with signals having different intensities on MRI sequences.

Conclusions: In conclusion, results of the current study have demonstrated that assessment of blood flow and vascular diameter may be important for ruling in VBI. Nevertheless, the intensity of signals derived from vessels seems not reveal any data of diagnostic significance in these cases. Further studies on larger populations may allow development and exploration of newer diagnostic techniques and clues for VBI.

Keywords: Vertebrobasilar insufficiency (VBI); diagnosis; magnetic resonance imaging (MRI); radiology

Submitted Jul 21, 2015. Accepted for publication Aug 10, 2015.
doi: 10.3978/j.issn.2223-4292.2015.09.02
View this article at: http://dx.doi.org/10.3978/j.issn.2223-4292.2015.09.02

Introduction

Vertebrobasilar insufficiency (VBI) is an enigmatous disorder with an obscure underlying pathophysiology. While some authors suggest that thromboembolism is the main cause, others advocate that there is a hemodynamic phenomenon which resources from the compromise of blood flow velocity in vertebral arteries (1-3).

Evaluation and quantitative analysis of blood flow in vertebrobasilar system may be useful for establishing diagnosis. Flow, volume, peak systolic or end diastolic flow rates and vascular diameter are among radiological parameters used in this purpose. However, the diagnosis

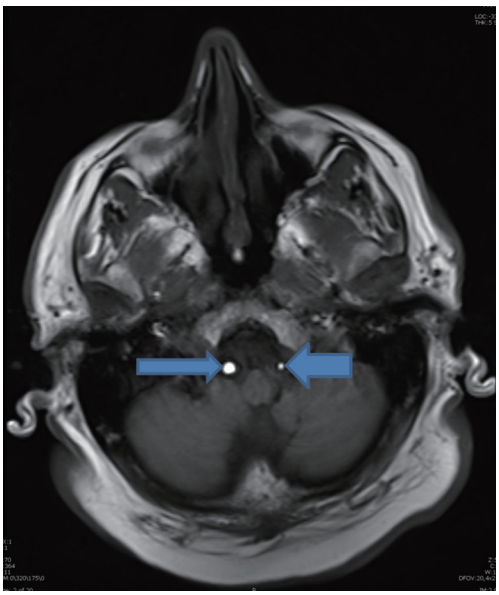

Figure 1 On non-contrasted T1-weighted axial MRI, loss of signal void appearance caused by slow flow in both vertebral arteries (arrows), and vascular flow signal (= entry slice phenomenon) were detected. Left vertebral artery (short arrow) has a thin diameter, and it is hypoplastic. MRI, magnetic resonance imaging.

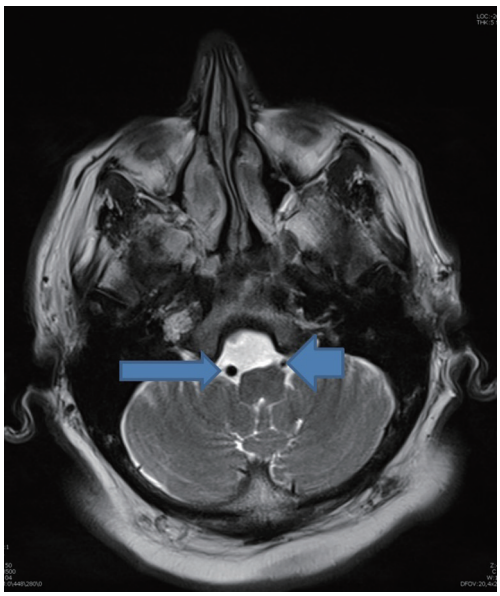

Figure 2 On non-contrasted T2-weighted axial MRI of the same patient demonstrates signal-void appearance in both vertebral arteries (arrows) due to slow flow rate. In these sequences, relative to T1-weighted non-contrasted images of the same patient, normal faster vascular flow was obtained. MRI, magnetic resonance imaging.

of VBI still constitutes a diagnostic challenge because its manifestations are subjective and difficult to quantify (4).

Owing to the non-tapered and plain configuration of vertebral arterial system in the cervical segment, flow measurements seem to be reliable (4). However, validation of normal values and reference data for radiological standards of blood flow is troublesome and further assessment of the vertebrobasilar circulation by means of noninvasive studies may hopefully provide further insight into the pathophysiological process of VBI.

Doppler ultrasonography and magnetic resonance imaging (MRI) are two important measures for diagnosis of VBI (5,6). On T2 weighted noncontrast axial MRI sequences, "slice-entry phenomenon" can exist due to the variability of blood flow in vertebral arteries (3). Accelerated blood flow results in failure of detection of protons leading to hypointense (black) appearance of intravascular structures. In contrast, decreased blood flow allows coding of protons and resulting in hyperintense (white) images in T2 weighed sequences (7).

The main aim of this case-control study was to compare the radiological features of blood flow of VBI under Doppler ultrasonography and MRI views. In this purpose, blood flow, vessel diameter, mean, peak systolic and end diastolic velocities, resistive and pulsatility indices were evaluated in VBI patients and healthy controls. Any association between signal intensities in T2 weighted axial MRI views of vertebrobasilar systems and radiological characteristics of blood flow in Doppler ultrasonography were sought to explore any novel diagnostic clues.

Materials and methods

Study design

Subsequent to obtaining written informed consent from all participants, 18 VBI patients, and 58 controls were enrolled. The whole group consisted of 54 women (71.1%) and 22 men (28.9%) with an average age of 46.86±13.53 (range, 20-76).

Patients have initially admitted with clinical signs of VBI such as vertigo, drop attacks, tinnitus, and ataxia. They were referred to the radiology department with the presumable diagnosis of VBI. Confirmation of diagnosis was made based on Doppler ultrasonography and MRI/magnetic resonance angiography (MRA). MRI and MRA were performed in one sitting (*Figures 1,2*). Signals of T2 weighted noncontrast

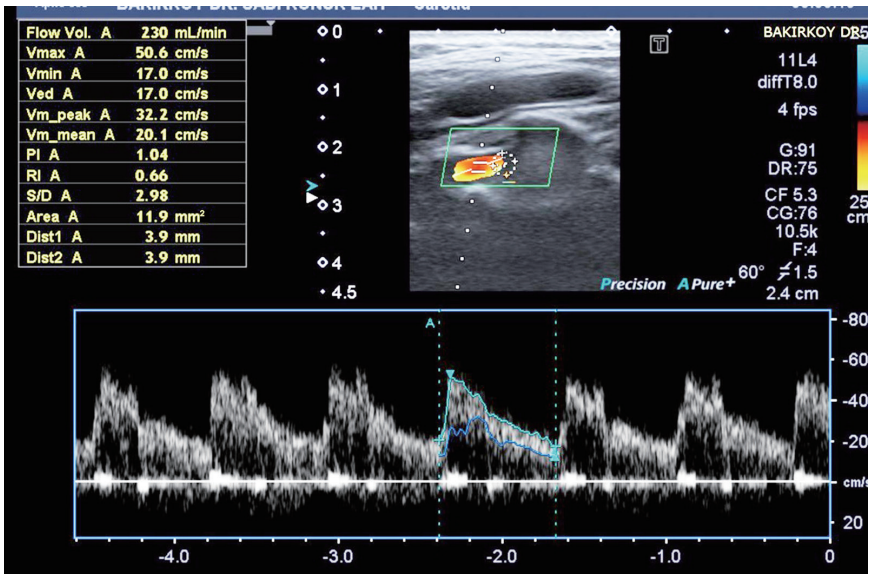

Figure 3 On the Doppler US examination, the right vertebral artery with normal flow parametres, flow volume, and diameter is seen. All Doppler examinations were performed at C2-C6 intercostal levels.

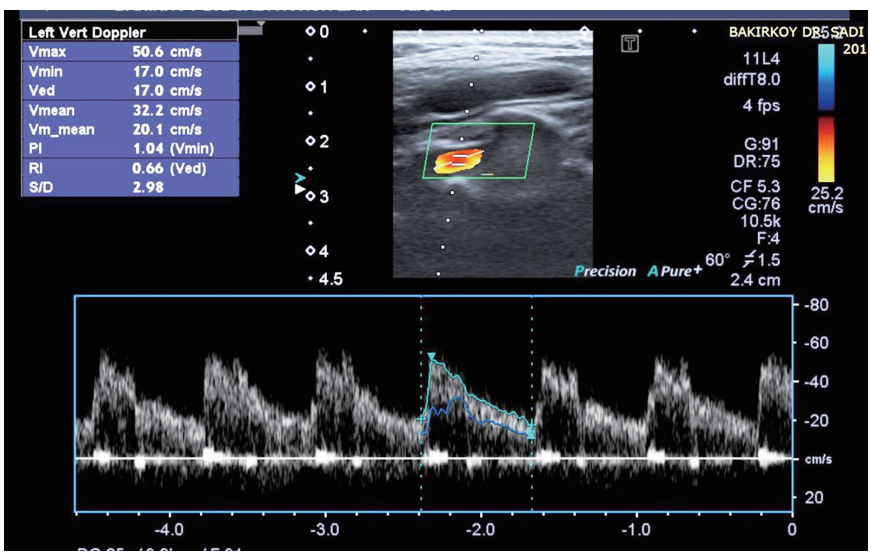

Figure 4 Doppler US of the left vertebral artery of the same patient demonstrates decreased flow parameters, flow volume, and diameter secondary to hypoplasia, As it would be remembered, on T1-weighted images, increased signal intensities in both vertebral arteries due to slow-flow phenomenon (entry slice phenomenon) were elicited. However on Doppler examination, normal values on the right, and decreased values on the left vertebral arteries were obtained. Besides on T2-sequence, normal vascular flow signal was elicited. These changes in flow signal seen on noncontrasted T1, and T2 sections due to entry slice phenomenon can erroneously mislead us to think of slow flow phenomenon. Thus, it can unnecessarily cause realization of additional examinations as MR-angiographic examinations.

MRI on signals of both vertebral arteries were examined to compare the radiological features to data derived from Doppler ultrasonography (*Figures 3,4*). Radiological evaluation was made by the same staff radiologist (EC) having 5 years of experience in neuroradiology. MRI was made on circular head and neck sequences using Philips 0.5T Gyroscan T5-NT device (MagNET, South Kensington, London, UK).

Diagnosis of VBI was set if the total blood flow through bilateral vertebral arteries was less than 200 mL/minute in Doppler ultrasonography (8). Toshiba SSA 270A colour Doppler ultrasound was used together with 5 and 7.5 mHz transducers (Toshiba Medical Systems Corp., Otawara-shi, Tochigi-ken, Japan). The blood flow and velocity of vertebral arteries were assessed by a single measurement performed by the same radiologist (EC) between 3rd and 4th cervical vertebrae with a Doppler angle of 45-65°.

MRA was carried out using 2D cine phase device on a 1.5 T machine for quantitative evaluation of blood flow. Flow encoding was encoding in a caudal to cranial direction and sequence parameters, imaging plane and pixel intensities were adjusted as described by Kato *et al*. (5). Sequence parameters were as follows: 40/11.8/2 (TR/TE/NEX); flip angle, 30 degrees; matrix, 256×192; field of view, 18 cm; section thickness, 5 mm; interpolated phases per RR interval, 32. Velocity encoding was adjusted to a maximum value of 150 cm/s. Flow encoding direction was from caudal to cranial. Exclusion criteria included uncontrolled hypertension, cardiac failure, subclavian steal phenomenon, hypoplastic vertebral artery, patent posterior communicating arteries or segmental stenosis of vertebral artery.

Outcome parameters

Descriptive parameters (age, gender) and radiological features of vertebral arterial blood flow in Doppler ultrasonography and MRI views were noted in both VBI and control groups. Characteristics of blood flow consisted of peak systolic and end diastolic flow rates, resistance and pulsatility indices, mean velocities, flow rates and diameter.

Pulsatility index was defined as the difference between peak systolic and minimum diastolic velocities divided by the mean velocity during cardiac cycle (9). Resistance index indicates is a measure of pulsatile blood flow that reflects the resistance to blood flow due to microvascular bed distal to the measurement site (10).

Signal appearances on MRI sequences on both sides were classified as either hypo- or hyperintense according to the speed of the blood flow which constitutes the basis of "slice entry phenomenon".

Statistical analysis

Data were analyzed using the IBM Statistical Package for Social Sciences (SPSS) Statistics 20 software (SPSS Inc., Chicago, IL, USA). Frequency distribution was calculated for categorical variables, while descriptive statistics were established for continuous variables. Normal distribution of continuous variables was evaluated with Kolmogorov Smirnov test. Comparison of two independent groups was made with Independent-Samples T test and Mann-Whitney U test. Categorical variables were compared using exact method for Pearson Chi Square test. Quantitative data were shown as mean, standard deviation, median, minimum and maximum values. Confidence interval was 95% and level of significance was set at $P<0.05$.

This case-control study was carried out in the radiology department of our tertiary care center after the approval of the local Institutional Review Board.

Results

Descriptive parameters (age and gender) did not display any significant difference between VBI and control groups (*Table 1*). Comparative overview of variables under investigation is shown on *Table 1* and interestingly, only blood flow and vessel diameter were significantly decreased in VBI patients for both left and right sides ($P<0.001$). Other parameters did not exhibit any remarkable difference between VBI and control groups. Presence of lacunar infarcts in both cases and control groups also did not show significant difference.

Distribution of signals in VBI and control groups did not reveal any noteworthy differences (*Table 2*). In other words, the alteration of blood flow in VBI seemed not to result in any alterations of signal intensities on T2 weighted MRI sequences that may possess diagnostic value in the current series.

Blood flow characteristics in cases revealing either dark or opaque signals on MRI images are demonstrated in *Table 3*. No significant differences could be observed for any parameters between cases presenting with different signal patterns.

Discussion

In this study, we attempted to assess whether signal intensities on T2 weighted noncontrast MRI views and radiological findings derived from Doppler ultrasonography may have a diagnostic value for VBI.

VBI constitutes a diagnostic challenge and determination of absolute and clear-cut definitions cannot be made for thresholds of VBI. Furthermore, even non-vascular factors such as osteophytic spurs of cervical vertebra may mimick VBI even if vertebral arterial blood flow is normal. It

Table 1 Descriptive and radiological parameters in VBI patients and controls

Variable		Groups		P value
		VBI	Control	
Age		47.56±14.60	46.64±13.30	0.803
Gender (male/female)		8/10	14/44	0.097
Right	Peak systolic flow velocity	37.36±12.83	44.10±16.18	0.111
	Resistance index	0.67±0.12	0.70±0.14	0.558
	Flow	75.51±40.23	131.35±57.89	<0.001*
	Diameter	3.22±0.50	3.53±0.46	<0.001*
	End diastolic flow velocity‡	13.90-10.15	13.40-6.88	0.807
	Pulsatility index‡	1.09-0.58	1.27-0.42	0.261
	Mean velocity‡	11.30-8.20	14.05-7.17	0.328
Left	Peak systolic flow velocity	42.32±15.52	46.09±19.74	0.461
	Resistance index	0.66±0.09	0.65±0.14	0.701
	Flow	89.31±40.90	170.11±83.67	<0.001*
	Diameter	3.34±0.61	3.92±0.54	<0.001*
	End diastolic flow velocity	14.16±6.11	15.70±7.38	0.424
	Pulsatility index‡	1.18-0.57	1.13-0.42	0.718
	Mean velocity	13.33±4.62	15.67±6.93	0.184

*, statistically significant; ‡, expressed as median-interquartile range; the other variables are shown in median ± standard deviation. VBI, vertebrobasilar insufficiency.

Table 2 Distribution of signal intensities of noncontrast axial T2 weighted magnetic resonance images in vertebrobasilar insufficiency (VBI) patients and the control group. Hypointense signal is consistent with fast blood flow, whereas hyperintense signal indicates slow blood flow

Side	Signal intensity	Groups		P value
		VBI	Control	
Right	Hypointense	16	56	0.206
	Hyperintense	2	2	
Left	Hypointense	18	56	1.000
	Hyperintense	0	2	

has been postulated that VBI symptoms maya rise due to microcirculation problems in the presence of completely normal looking vertebral arteries (4,11).

Color Doppler ultrasonography is commonly for evaluation of the obstructive disease of the arteries (12-14). Attributed to technical difficulties, vertebral arteries have not been considered frequently in terms of both clinical and radiological aspects (12,15). However, increased awareness on VBI has changed this tendency especially in the last decade.

Visualization studies showed that imaging of the vertebrobasilar arteries can be extremely complex and variable. During the MR experiments, the same segment of a vessel could appear very different depending on the pulse sequence (16). The findings in MRI were classified with respect to the degree of ventricular dilatation, callosal degeneration, and lacunar infarction (2,17). Assessment with MRA was made according to the degree of pathological changes in the blood vessels (5). Not only a significant difference was observed in lacunar infarction on the MRI findings between VBI cases and normal controls, but also there were significant differences in side differences in the vertebral artery between VBI cases and peripheral vertigo and normal controls. Nakagawa *et al.* compared

Table 3 Blood flow characteristics in vertebral arteries of cases presenting with signal patterns of different intensity in T2 weighted noncontrast magnetic resonance images

Side	Parameter	Signal intensity		P value
		Hypointense	Hyperintense	
Right	Peak systolic flow velocity	42.77±16.00	37.65±5.30	0.528
	Resistance index	0.69±0.14	0.62±0.10	0.286
	Flow	118.78±60.04	106.28±40.10	0.683
	Diameter	3.44±0.49	3.73±0.38	0.256
	End diastolic flow velocity‡	13.65-8.18	12.60-5.30	0.907
	Pulsatility index‡	1.26-0.48	1.01-0.60	0.174
	Mean velocity‡	13.90-7.82	12.85-4.32	0.658
Left	Peak systolic flow velocity	45.32±19.02	40.70±6.93	0.734
	Resistance index	0.65±0.13	0.63±0.08	0.809
	Flow	150.86±84.13	155.00±21.21	0.683
	Diameter	3.77±0.61	4.30±0.00	0.225
	End diastolic flow velocity	15.37±7.13	13.95±7.85	0.782
	Pulsatility index‡	1.25-0.42	1.245	1.000
	Mean velocity	15.12±6.56	14.95±5.17	0.971

‡, expressed as median-interquartile range; the other variables are shown in median ± standard deviation.

the MRA results of middle-aged and older VBI cases with those of age-matched peripheral disorder cases (6). In their study, MRA results were quantitatively assessed by scores determined on the basis of the severity of stenosis in the vertebral arteries and basilar artery. The severity of stenosis and the MRA score of VBI cases were significantly higher than those of peripheral cases. They concluded that MRA can be of value as a screening examination for estimating vertebrobasilar blood flow and can provide helpful information for diagnosing VBI. Nakagawa *et al*., in another study, assessed the usefulness of evaluating basilar arterial flow by MRA (18). MRA results for patients with VBI were compared with those for age-matched individuals with no vestibular disorders. Their findings suggested that MRA is valuable for the estimation of vertebrobasilar hemodynamics. MRA evaluation of basilar artery stenosis appears to be suitable for identifying a high-risk group among VBI patients, since basilar artery stenosis can result in serious disabilities. We propose an etiology for hemodynamic VBI: a functional cerebral circulation disorder causes ischemia of the basal ganglia and leads to lacunar infarctions; furthermore, the side difference between the two vertebral arteries causes a circulation disorder in the vertebrobasilar system (2).

The slice entry phenomenon arises in MRI when blood with unsaturated spins flows in the observed slices. These spins will emit a strong signal attributed to their unsaturated status. The number of slices affected depends on the velocity of flow and the thickness of the slice, while the direction of the flow determines the slices are affected (17).

Our results have demonstrated that only blood flow and diameter of vertebral arteries seem to possess diagnostic potential to rule in VBI. Other parameters including peak systolic or end diastolic flow velocities, resistive and pulsatility indices seem not to provide any additional contribution. Moreover, signal intensities achieved from T2 weighted noncontrast MRI sequences are unlikely to have a remarkable value or any association with clinical or sonographic findings. Limitations of this study include relatively small sample size and performance of measurements by the same radiologist. Therefore, extrapolations and interpretations must be made with caution.

To conclude, results of the present study indicate that assessment of blood flow and vascular diameter may be important for ruling in VBI. On the other hand, signal intensity patterns of vessels in MRI seem not reveal any data of diagnostic significance in these cases. Further studies on larger populations may allow development and exploration of newer diagnostic techniques and clues for VBI.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Cakmakci E, Ozal ST, Ogutcu EK, Aydin A, Tunc S, Kaygusuz U, Cinar HG. Are there any novel radiological diagnostic clues in magnetic resonance imaging for vertebrobasilar insufficiency? Quant Imaging Med Surg 2015;5(6):846-852. doi: 10.3978/j.issn.2223-4292.2015.09.02

